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Selectively Placing Many Fractures in Openhole Horizontal Wells Improves Production

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Abstract

This paper summarizes stimulation results from an openhole horizontal well that was treated with a new fracturing process called hydrajet fracturing. With this process, operators can accurately place many fractures at different locations in a horizontal well without using sectional isolation techniques. In particular, the process uses high-pressure jetting to concentrate fracturing energy at a precise fracture location. Surface and downhole pressure recorders, flow recorders, and tracers obtained pertinent data for further study of the process. The well in this study was hydrajet-fractured with acid.

This study demonstrates that openhole horizontal wells can be hydrajet-fractured effectively and economically.

Introduction

Hydraulic fracturing is a common practice in today's oil industry. Since its inception in 1948,[1] the process has been improved by new fluid systems, resulting in increased volumes, proppant concentrations, flow rates, and pressures. Originally used in vertical wells, fracturing processes can now be used in horizontal wells, primarily cased wells.

When fracturing was a relatively new process, unknown phenomena caused numerous problems. Today, an understanding of well properties (massive leakoffs, tortuosities, limited entry, coplanar entry, frac direction, etc.) allows operators to maximize fracturing efficiency. In cased horizontal wells, fractures perpendicular to the wellbore can be effectively initiated if operators reduce perforation interval length, increase perforation density, and "slug" the well.[2] With the hydrajetting method, the well can be perforated coplanar with the preferred fracture plane and then fractured.[3]

References at the end of the paper.

In openhole horizontal wells, large, exposed wall surfaces cause high fluid loss, especially when natural fractures are present. Therefore, stimulations are limited to either uneconomical "hail mary" fracturing[4] (e.g., an all-out attempt at high-rate fracturing with absolutely no control of fracture placement), or well damage removal with movable pipe, such as coiled tubing.[5]

Hydrajet Fracturing

Operators and service companies have continually searched for ways to perform effective fracturing treatments. One such solution, hydrajet fracturing, was recently introduced as an alternative to traditional fracturing processes.[6] Using this economical method, operators can quickly and accurately place multiple fractures in the same well without using sealing elements.

The hydrajet fracturing method, based on a Bernoulli equation, maintains low wellbore pressures and initiates strategically placed fractures effectively. Fig. 1 shows a single horizontal well that consists of multiple large fractures placed strategically where hydrocarbons may exist. Each fracture can be formulated with different fluids such as sand slurries or acid, depending on the rock formation surrounding the fracture entry point. Moreover, numerous small fractures can be placed throughout the well, bypassing damaged areas. The process is economical because all of these processes can usually be performed in one trip down the well.

Hydrajet Fracturing Treatment Procedure

To perform a hydrajet fracturing job, operators must use a jetting tool with coplanar-adjusted jets. The jetting plane must approximately coincide (varying no more than 30°) with the reservoir's preferred fracture extension plane. The jetting tool also has a return bypass system, which is only needed if fluids must be reversed during the job.

While pumping fracturing fluids through the jets, the operator uses flow down the annulus to control bottomhole pressure and to supplement the proper fracture with fluid. Because the well becomes supercharged during fracturing, operators must use tools to maintain annulus pressure during pipe movement and install a tubing valve in the tubing string downhole to allow new connections to be made in the tubing.

To begin the job, the operator must pressurize the annulus until bottomhole pressure approaches a point just below the

predicted fracture extension pressure (FEP). Next, tubing pressure is increased until jet differential pressure reaches 4,000 to 5,000 psig. From this point, the fracturing process continues in a conventional manner with pad, fracture, and flush fluids delivered down tubing. The only difference in the process is that bottomhole annulus pressure must be maintained throughout the job.

Exceptions to this procedure exist, especially when cased wells are being fractured. If the casing is not perforated, a sand pill is pumped ahead of the pad fluid. Generally, a gelled fluid with a 1-lb/gal sand concentration is pumped for 3 to 5 minutes. Even if the well is not cased, the first stage in the job should include a smaller sand pill, because success of the hydrajet fracturing action (the process where annular fluid is suctioned into the producing formations) occurs only when a cavity is formed and a high stagnation pressure is established. As soon as the sand pill penetrates the casing, or when a cavity begins to form, annular pressure will drop, indicating that fluid is being suctioned into the cavity, thereby initiating a fracture.

Next, pad fluid is pumped into the well, followed by the fracturing fluid, which can consist of sand-laden gels or acid. Volumes and flow rates for these fluid stages are computed with conventional job design programs. As mentioned previously, annular flow must be maintained to keep pressure around the jets slightly below the FEP.

After the fracture has been completed, flush fluid is pumped to clear the tubing. However, a more efficient fluid system design places a sand pill at the jets, allowing the operator to move directly to the next fracturing stage. This design will reduce time and fluid needed for the job. However, sand could settle in the tube. In horizontal wells, settling is acceptable; when pumping resumes, fluid velocities in the tubing will be sufficient to force the sand back into the flow.[7]

Subsequent fracturing stages are performed similarly, although pressure changes will occur because of the pressure drop differences in both the tubing and annulus. Operators can compute fluid friction losses for the length of the job and then use the data to maintain bottomhole pressure conditions.

Acid Frac Treatment of a Well

To test the hydrajet fracturing technique, we selected a candidate horizontal well in Eunice Monument Field in Lea County, New Mexico. This well has been in production for more than 30 years, and production had diminished substantially. A 4¾-in. lateral was drilled through the well's 5½-in. casing at a kickoff point of 3,670 ft. The true vertical depth (TVD) is 3,821 ft at the heel and 3,650 ft at the toe. The well penetrates the Grayburg formation, which contains dolomite with many sand lenses. These horizontal lenses potentially reduce vertical permeability in the formation, making the well a good candidate for fracturing.

The horizontal section of this well measures about 1,600 ft, penetrating the formation, which has an approximate thickness of 171 ft. Using acid, operators placed eight fractures at the depths specified in **Table 1**.

Like any fracturing job, pressures, flow rates, and fluid volumes must be computed accurately. However, the procedure for computing a hydrajet fracture differs slightly because of the equipment involved. First, when tubing is used, flow rates are generally limited because friction increases at high flow rates. Second, the jetting tool must be designed to deliver high rates and high pressures through numerous jets. Third, annular flow cannot be predicted because it is contingent upon the well's leakoff characteristics, which continually change throughout the job. These changes are generally attributed to the initiation of new fractures and the presence of leakoff-control additives or other contaminants in the fluid system.

The first two computations can be made with conventional fluid friction and flow techniques. However, when sizing the job, the engineer may be subjected to trial-and-error iterations. For example, by using fracture design programs, we should be able to determine flow requirements for a certain fracture development scheme. This flow rate, however, is limited by the tubing size.

A prejob well injection will help operators predict the annular flow rate required to pressurize the well during the job. This information allows us to better predict the annulus flow rate required during the initial stages of the job. Using fluid friction data and the required BHP, the range of surface pressures to pressurize the bottomhole annular region can be computed for a range of flow rates. As mentioned earlier, we must maintain this bottomhole pressure a little below the FEP. It was estimated that the fracture gradient is about 0.5 to 0.6; hence, the FEP is estimated to be about 2,200 psig. During the job, annular flow requirements will increase, which will change the pressure requirements, as shown in **Fig. 2**. Fig. 2 represents surface annular pressure requirements which takes into account the hydrostatic pressure and annular fluid friction.

During the job, the annulus pressure limit was set at 800 psi to ensure that the aging casing's residual strength could contain the pressures of the stimulation job. Fig. 2 shows that a 2,200 psig BHP can be obtained with such pressure, as long as flow rates do not exceed 8 bbl/min. On the basis of a preceding paper,[6] the stagnation pressure front in the fracture can be as high as 1,100 psi above this annular pressure. However, as assumed and suggested in the paper, the stagnation pressure increase is 400 psig, which means that pressures somewhere in the fracture are in excess of 2,600 psig. With this pressure, it is likely that a fracture will begin and extend with little effort.

Unlike the capital-intensive high-rate fracturing method (which generally requires 50 to 80 pumping units on-site), this type of fracturing job is relatively simple and can be accomplished with two blenders and a few pump units (**Fig. 3**). The job was simple because of the rates and pressures used; pressure in the tubing was 7,500 psi and the pump rate was 16 bbl/min.

For this study, data was collected during the job for further analysis. A downhole data recorder (**Fig. 4**) provided live data transmission throughout the job. Fracturing fluids were tagged for further fracture identification purposes. **Fig. 5** shows the

assembly of various tools when they were installed in the well. On top is a 12-jet jetting tool, preceded sequentially by the centralizing bypass valve, perforated sub, and the data recorder with its transmission system. These tools were lowered into the well, and the jets were positioned at a depth of 5,300 ft.

As soon as the tool was positioned, fracturing began. After the well was charged, a sand pill was pumped into the tubing at a relatively low pressure until it reached the bottom of the jets. Next, annulus pressure was increased to about 800 psi and pumping through the tube began at 7,500 psig. Within seconds, annulus pressure dropped, indicating that the hydrajet fracturing action, or the Bernoulli action, had started. At this point, annular fluids were being suctioned into the fracture, so the annulus flow rate was increased to maintain consistent pressure.

After the sand pill, pad fluid was pumped. For this job, about 5,000 gal of pad was used for each fracture. This pad was followed by 5,000 gal of 17% acid. For this job, the sand pill and pad for the next stage were used as the flush fluid. The job log is shown in **Fig. 6**, and a compilation of the entire job is shown in **Fig. 7**.

The most interesting item from Figs. 6 and 7 is the pressure decline portion of the downhole pressure plot. A combined plot (**Fig. 8**) shows how the pressure decline rate drops continually after each fracture; in the first fracture, the pressure decline is much faster than in the subsequent treatments. Each time a new fracture is created, the volume of the well cavity increases, resulting in a slower pressure-decline rate. This decrease apparently becomes less significant when the effect of charging the well becomes more significant.

The creation of these fractures is more apparent in **Fig. 9**, in which the tracer log clearly identifies each fracture near its targeted position.

Production Results

Because the well is located in a heavily depleted area and has been in production for decades, it does not exhibit the level of improvement expected from a younger well.

The Eunice well's recent history offers support for hydrajet fracturing. One year before treatment, the well was producing very little oil, essentially zero. It was treated with acid stimulation techniques, but production did not improve. Then, an acid fracture or injection was placed, and production increased to about 1 to 4 bbl/D. The result of this acid treatment could have caused the anomaly between Fractures No. 5 and 6 (Fig. 9).

After the hydrajet fracturing treatment, well production increased to as much as 50 bbl/D and water production declined. Since then, production has declined to about 30 bbl/D.

Conclusions

An effective new method for fracturing openhole horizontal wells has been presented. This hydrajet fracturing technique was implemented in a substantially depleted horizontal well in New Mexico. Pressure data and production data show good results.

Like any new process, a lack of resources prevents the widespread application of hydrajet fracturing. To make this new technology operationally feasible, researchers must design the proper downhole tools and create equipment to analyze multiple-fractured systems.

References

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Table 1–Acid Fracturing Treatment Depths

Total Measured Depth, ft	True Vertical Depth, ft
5,300	3,668
5,172	3,680
4,950	3,695
4,780	3,715
4,600	3,735
4,505	3,753
4,370	3,775
4,200	3,792

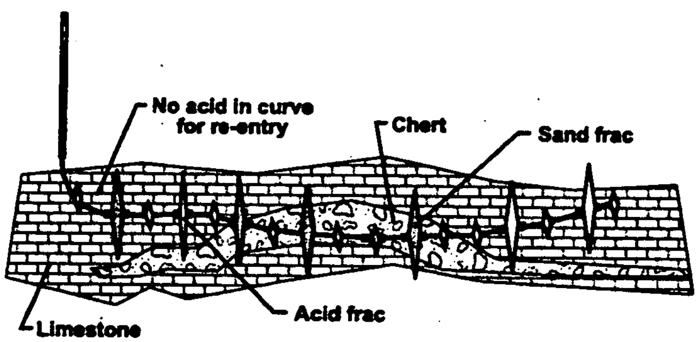

Fig. 1–Possible hydrajet completion.

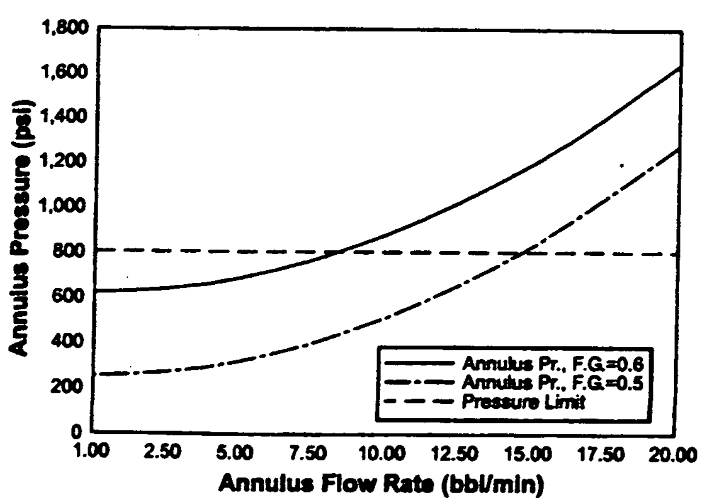

Fig. 2–Annulus pressure requirement chart.

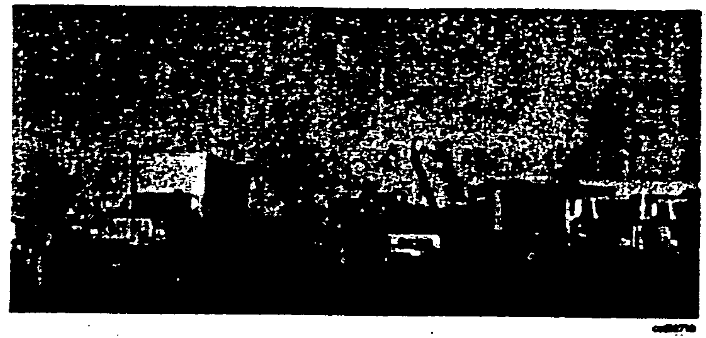

Fig. 3–Equipment on location.

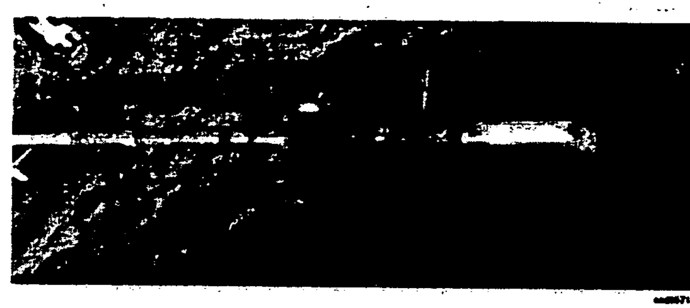

Fig. 4–Data recorder and transmission system.

Fig. 5–Tool installation.

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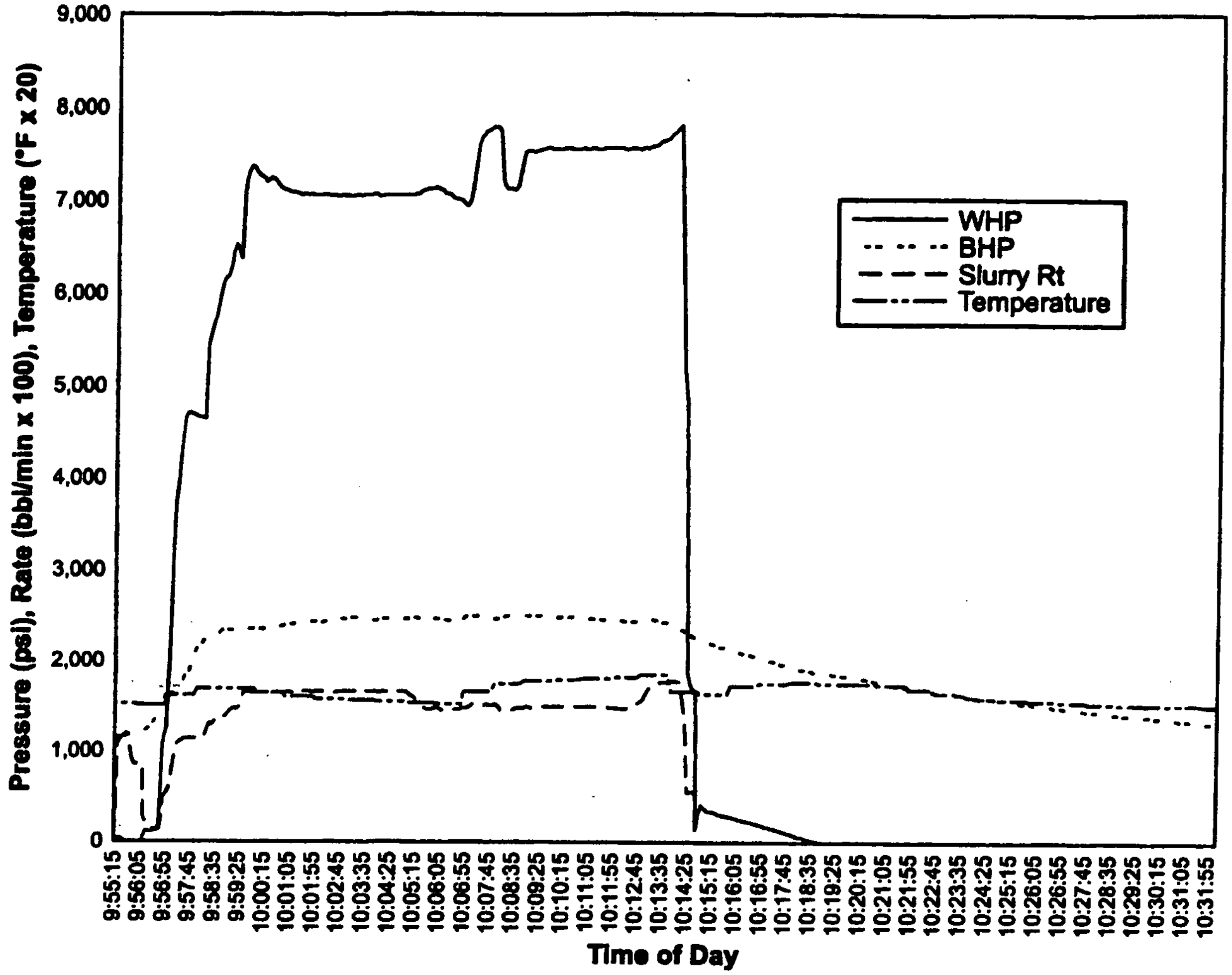

Fig. 6–Job data chart, Stage 1.

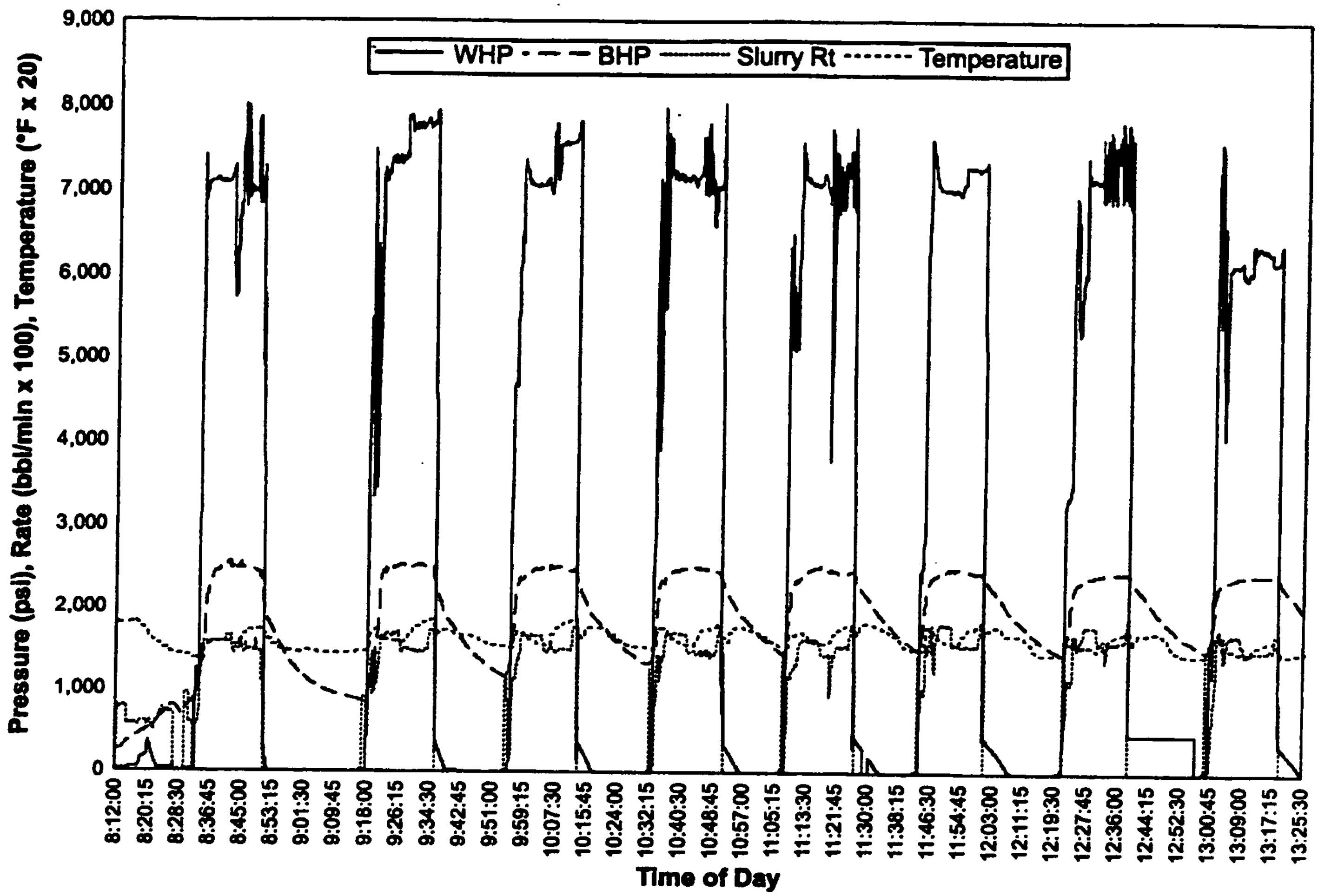

Fig. 7–Job composite plot.

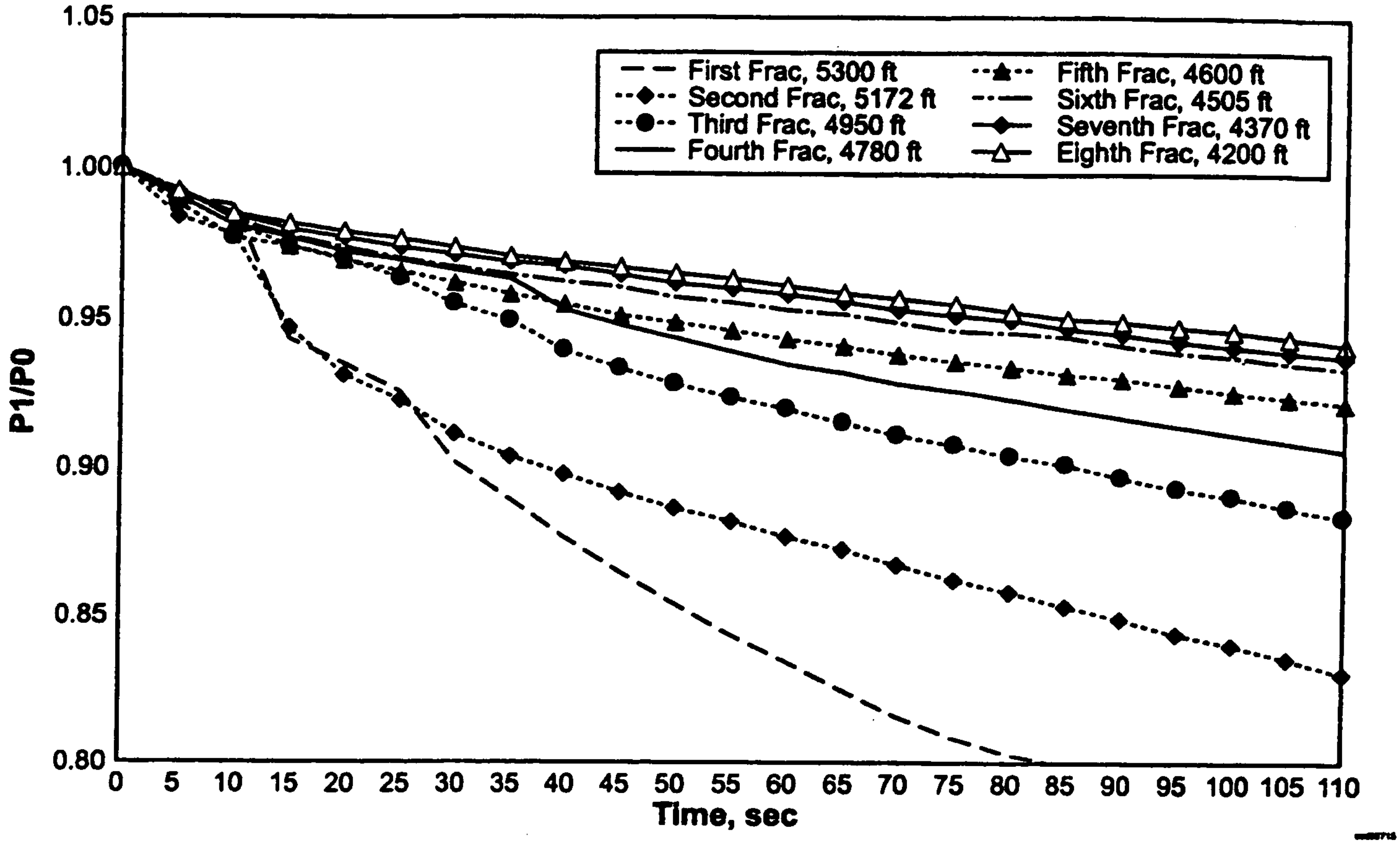

Fig. 8–Composite pressure decline curves.

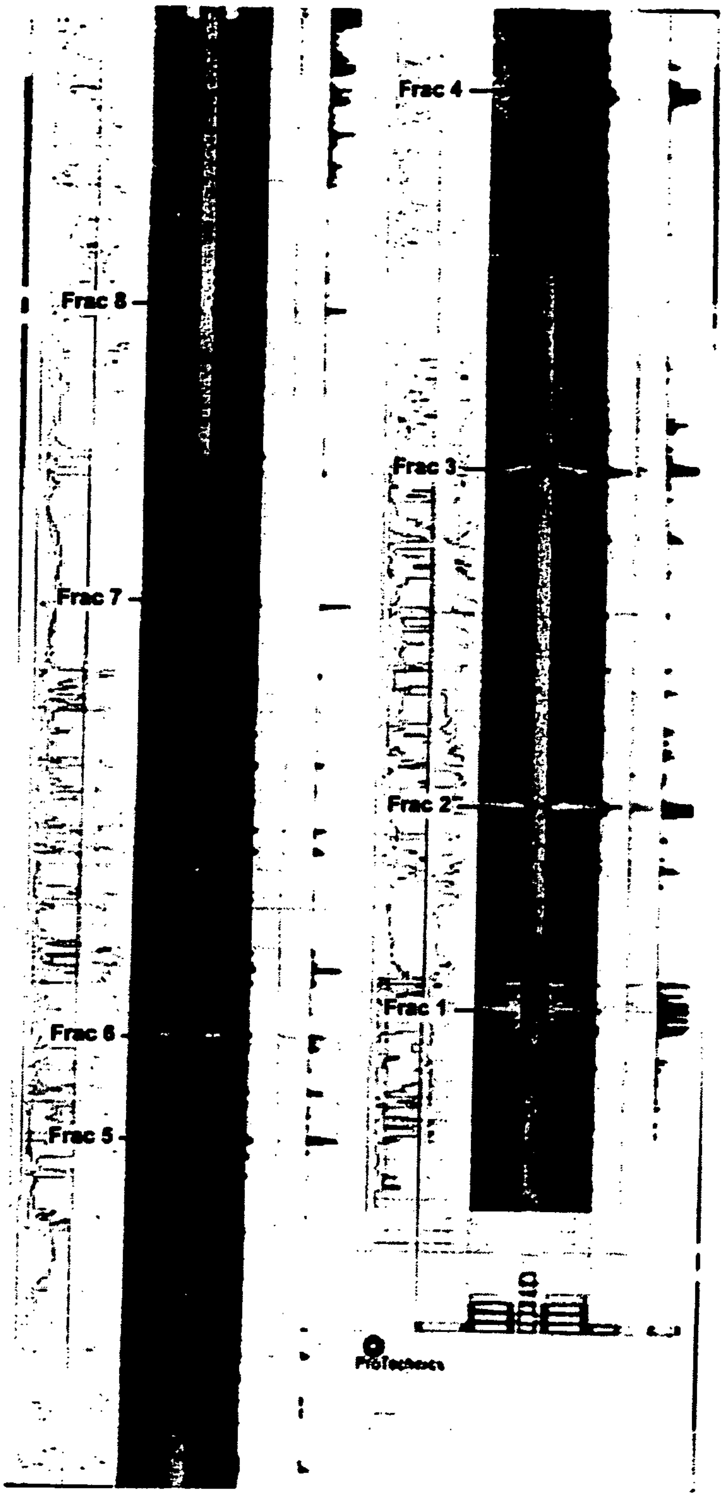

Fig. 9–Tracer log.

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